NITROGEN MINERALIZAT ION POTENTIAL Or NEEM (*AZADIHACHTA INDICA A. JUSS)* SEED CAKE AND ITS UTILIZATION IN SAVANNA SOIL

BY

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DECLARATION

I hereby declare that this thesis contains the report of my research work and has not been presented in any previous application for a higher degree. All information from other sources have been duely acknowledged.

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2ND MARCH, 1998
DATE

CERTIFICATION

This thesis entitled "Nitrogen Mineralization Potential of Neem (*Azadirachta indica A. Juss*) Seed Cake and its Utilization in Savanna Soil" by Idris, Sulaiman Ola meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, Zaria, Nigeria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This project is dedicated to: my mother **MALLAMA SULIYAT ABIYE IDRIS** for all her pains and sufferings in bringing me to this world; **ALHAJI SHEIKH IBRAHIM NIYAS KAOLAKH** and all the **Faithfuls** of **Tariqa Tijaniyat** all over the world.

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ABSTRACT

Laboratory incubation studies were earned out on a mixture of neem seed cake (2g) and soil (lOOg) to assess the N mineralizable potential of ncetn seed cake. Moisture content of the mixture was maintained by periodic addition of distilled water and the mixture was incubated at laboratory temperature for 14 weeks. During this time, KC1 extracts of the soil/nccm seed cake mixture were periodically analysed lor KI I,' - N and No_3 - N. The pH of the extracts were also determined.

Simple first order and modified first order E rate equations were fitted to the data obtained to quantify the potentially mineralizable N. Statistical treatment indicated that the modified first order E model gave a better fit than the classical first order model. From the calculated half lives, simple first order and modified first order E equations indicated that neem seed cake could be added to soil at $4V_2$ and 6 weeks respectively alter planting (for a maize that tassels at the 8th week of planting). This would ensure that hall ol the potentially mineralizable N would be available for the maize utilization.

Trvee cropping sessions of 6 weeks each were conducted in green house studies. At the end of every cropping, the shoot dry matter yield (SDMY), root dry matter yield (RDMY), nitrogen uptake of shoot (NS), nitrogen uptake of root (NR). and soil pH were determined. Soil available P was also determined at the end of first cropping.

The response to the application of neem seed eake in the trials as reflected in SDMY, RDMY, NS and NR indicated significant difference from the control experiment. Urea fertilizer and its interaction with the neem seed eake increased the dry matter yield and N uptake as compared to control. The interactive effect of neem seed eake and urea gave better response when 80kgN ha of urea were applied than when 40kgN ha of urea were used as reflected in dry matter yield and N uptake. All the soil amendments increased soil acidity relative to control experiment. All the plants exhibited *V* deficiency symptoms at lirst cropping.

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CHAPTER ONE

INTRODUCTION

Soil is the medium for the production of food by man. It is, therefore, important that the soil be well managed so that its exhaustion and degradation will be minimized (Abdulrahman, 1989).

About three quarters of Nigeria's total land area lies in the Savanna region. Savanna soils are predominantly sandy in nature and have inherently low fertility status (Jones and Wild, 1975). Nitrogen and phosphorus deficiencies are widespread in soils. It is no exaggeration that crop growth is limited more often by N deficiency than by any other nutrients. Plants absorb their N in the form of NH_4^+ and NO_3^-. The amount of N taken up by plants depend on what is supplied from inorganic fertilizers and mineralization (conversion of organic N into inorganic N) from soil organic matter (SOM). The amount of N obtained by the plants from SOM depends on the balance between mineralization, immobilization (conversion of inorganic N into organic N), and losses from volatilization (Tisdale and Nelson, 1975).

In Nigeria, projected fertilizer import for direct consumption in 1994 was about 850,000 metric tonnes with an estimated subsidy of 8.7 billion naira (Ogunfowora, 1996). The benefit of inorganic fertilizers in food production, and their adverse effects on Savanna soils are not yet fully documented. However, long-term use of inorganic fertilizers has a potential of inducing soil acidity and nutrient imbalance (Bache and Heathcote, 1969).

In view of the enormous costs and subsidies that go into the procurement of inorganic fertilizers, it is imperative that alternative soil management technologies which does not rely only on inorganic fertilizers but utilize locally avaiable organic materials to supply the needed requirement be developed.

An on-going project at the National Research Institute for Chemical Technology, Zaria deals with extraction of oil from neem seeds for industrial and pharmaceutical uses. The by-product hereby and thereafter referred to as neem cake, has about 6-7% N and

42% protein. It is the hypothesis of this study that neem cake may have agronomic value if N in the cake can be readily mineralized for plant use. This will reduce the dependence on inorganic N fertilizer. This study is therefore to demonstrate the potential for improving the N fertility of Savanna soils by neem cake. The neem tree is a well adapted plant in all the ecological zones of Nigeria (Jackai, 1993).

The objectives of this study are:

(1) To assess the potentially mineralizable N in neem cake

(2) To determine the effect of neem cake on maize dry matter yield and N uptake under green house conditions.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Neem and its Origin

Neem tree belongs to Mahogany family, Maliaceae, and is classified as *Azadirachta indica A. Juss.* Its origin is uncertain. Some have suggested that it is native to the Indian subcontinent, while others attributed it to dry forest areas of South and Southeast Asia (NRC, 1992). Neem was reportedly brought to Africa earlier this century. Since then it has spread to many countries particularly South of the Sahara where it provides both fuel and lumber. In Nigeria, it has been successfully planted in Borno areas. In the 1930's several thousand of seedlings from the first plantaion were replanted in Sokoto, Katsina, and Kano provinces. Today, there are considerable plantations for firewood and construction materials throughout Northern Nigeria (NRC, 1992).

2.2 Economic Importance of Neem

Neem has a potential for controlling insects (Schmutterer, 1985, 1990; Jacobson, 1986). Extracts from its bitter seeds and leaves have insecticidal effects (NRC, 1992). Schmutterer (1990) reported that when 4 locust nymphs were treated with neem oil, only 3 got half way out of terminal molt and died. The fourth molted completely but had fatal deformities. Application of neem oil extracts to the larva of Gypsy molt resulted in an incomplete molt. The nymphs of the variegated grasshopper, *Zonocerus variegatus*, treated with neem extracts emerged as adults with no antennae and with defective wings.

In Borno State, Nigeria local cowpea growers use aqueous leaf extracts to keep off grasshoppers during dry season (Jackai, 1993). The effect of neem on grasshoppers has been presumed to be due to its antifeedant properties (Butterworth and Morgan, 1971; Olaifa and Adenuga, 1988). The most widely known pest control use of neem is for post-harvest grain protection against *Callosobruchus* spp in cowpea (Ivbijaro, 1983; Sowunmi and Akinnusi, 1983) and *Sitophilus zeamais motsh* (Kossou, 1989). Jackai (1993) evaluated different neem formulations in two major cowpea pests, the pod borer, *Maruca testulalis* Greyer and pod sucking insect, *Clavigralla tomentosicollis* Stall. A

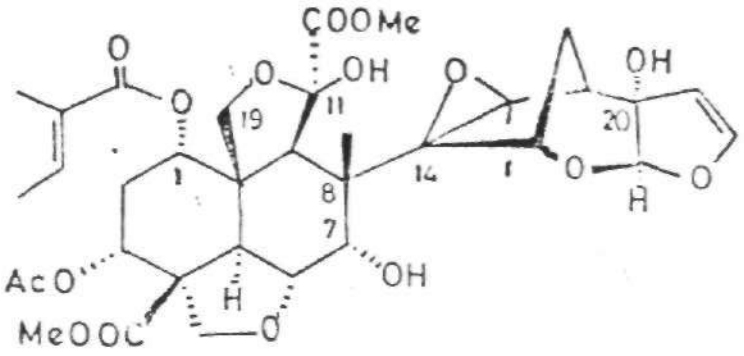
high mortality rate was recorded indicating the inability of the pests to feed due to phagodeterrence factor in the neem. The active principles responsible for the insecticidal properties has been found to be a mixture of five related compounds. These are azadirachtin, salannin, meliantriol, nimbin and nimbidin (Fig. 2.1).

Over the years, the Indians have cleansed their teeth with twigs from neem trees, smeared skin disorder with neem leaf juice, neem tea as a tonic and placed neem leaves in their beds, cupboards, grainbins to ward off troublesome bugs. They also believe neem possesses miraculous power (NRC, 1992).

Neem is effective against certain human pathogenic fungi which hitherto, have been difficult to control with synthetic fungicides (Khan and Wassilew, 1987). The seed suppresses several species of pathogenic bacteria (Schneider, 1986; Patel and Trivedi, 1962) and also possesses antiviral properties. Crude neem extract is effective against small pox, chicken pox and fowl pox by absorbing the viruses, thereby preventing them from uninfected cells (Rao *et al.*, 1969; Rae and Sethi, 1972).

Neem is widely recognised to have antimalarial activity. The leaf extract is used to treat malaria. Oil from neem is a powerful spermicidal and may be used for birth control. Indeed, neem oil formulation called Sensal is now sold in India for contraceptive purpose. However, consumption of neem oil can be dangerous. Doses as low as $5cm^3$ have killed infants, while animals have shown acute toxicity to 14-$24cm^3$ per kg of body weight (Ghandi *et al.*, 1988). Antitrypanocidal activity of neem against *Trypanosoma brucei brucei* has been reported (Nock *et al.*, 1993).

Apart from its possible pharmaceuticals and pesticides applications, it provides other useful services to humanity. Its seed is used in the industrial production of soap, waxes, lubricants and fuel for heating and lighting purposes (NRC, 1992).



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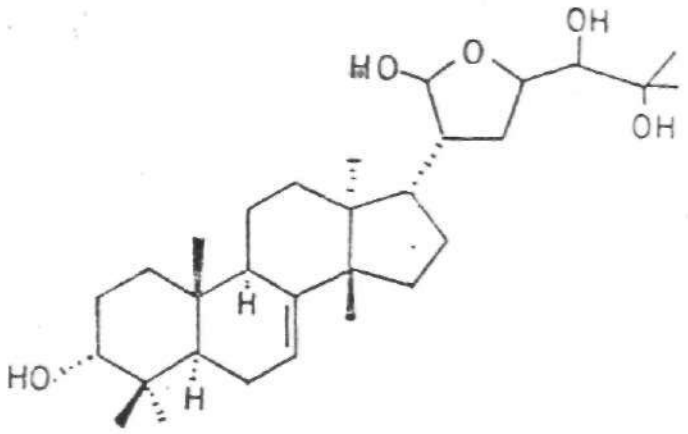

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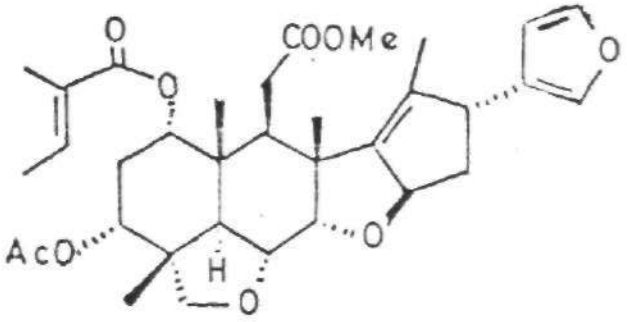

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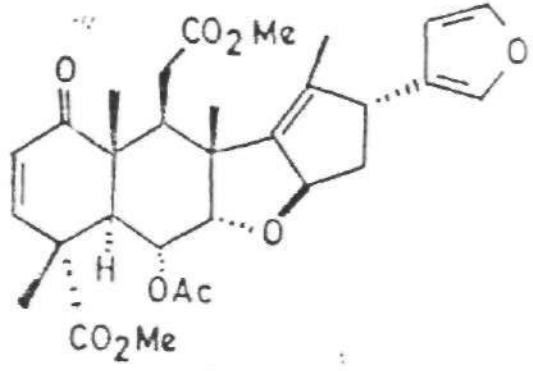

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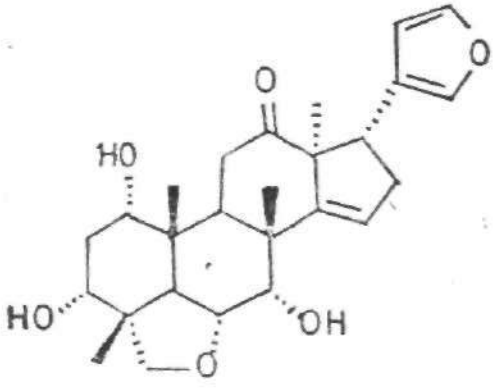

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FIGURE 2.1: CHEMICAL STRUCTURE OF NEEM'S MAIN INGREDIENTS

2.3 Nitrogen Cycle in the Soil

The modified schematic representation of N cycle in soil is presented in Fig. 2.2 Nitrogen fixation is one of the major reactions of the N cycle in soil environment and it plays an important role in soil fertility (Arima and Yoshida, 1982). The N in air is fixed principally by two methods:

(a) bacteria in root nodules which are able to fix N directly from air, and

(b) certain non-symbiotic bacteria are able to absorb N directly from atmosphere (Fig. 2.2).

To enrich the soil, N may be supplied either in the inorganic (commercial fertilizer) or organic form (manure). When organic fertilizer is added to soil, it undergoes ammonification and nitrification processes. During these processes the inorganic N produced are taken up by plant as available N.

The ammonification process is carried out by non-specialized organisms while the NO_3^- - N or NO_2^- - N are produced by specialized microorganisms (Black, 1968).

2.4 Neem in Soil Fertility Improvement

Neem has a high potential for soil fertility maintenance and improvement. The neem cake and the leaves are promising soil amendments. Radwanski and Wickens (1981) indicated that the cake contains more Na, K, Ca, and Mg than the farm yard manure or sewage sludge and has long been used in India to improve soil fertility (Jackai, 1993; Ketkar, 1983; Grant *et al.*, 1983). The cake protects plant roots from nematodes and white ants probably due to the residual limonoids, a group of tetranortipterpinoids of which azadirachtin is the most active (Jackai, 1993; NRC, 1992). Asante (1985) observed that when neem cake was applied as a drench, it enhanced tomato yield. Similar effects were observed on cowpea (Cobbinah and Osei-Owusu, 1988).

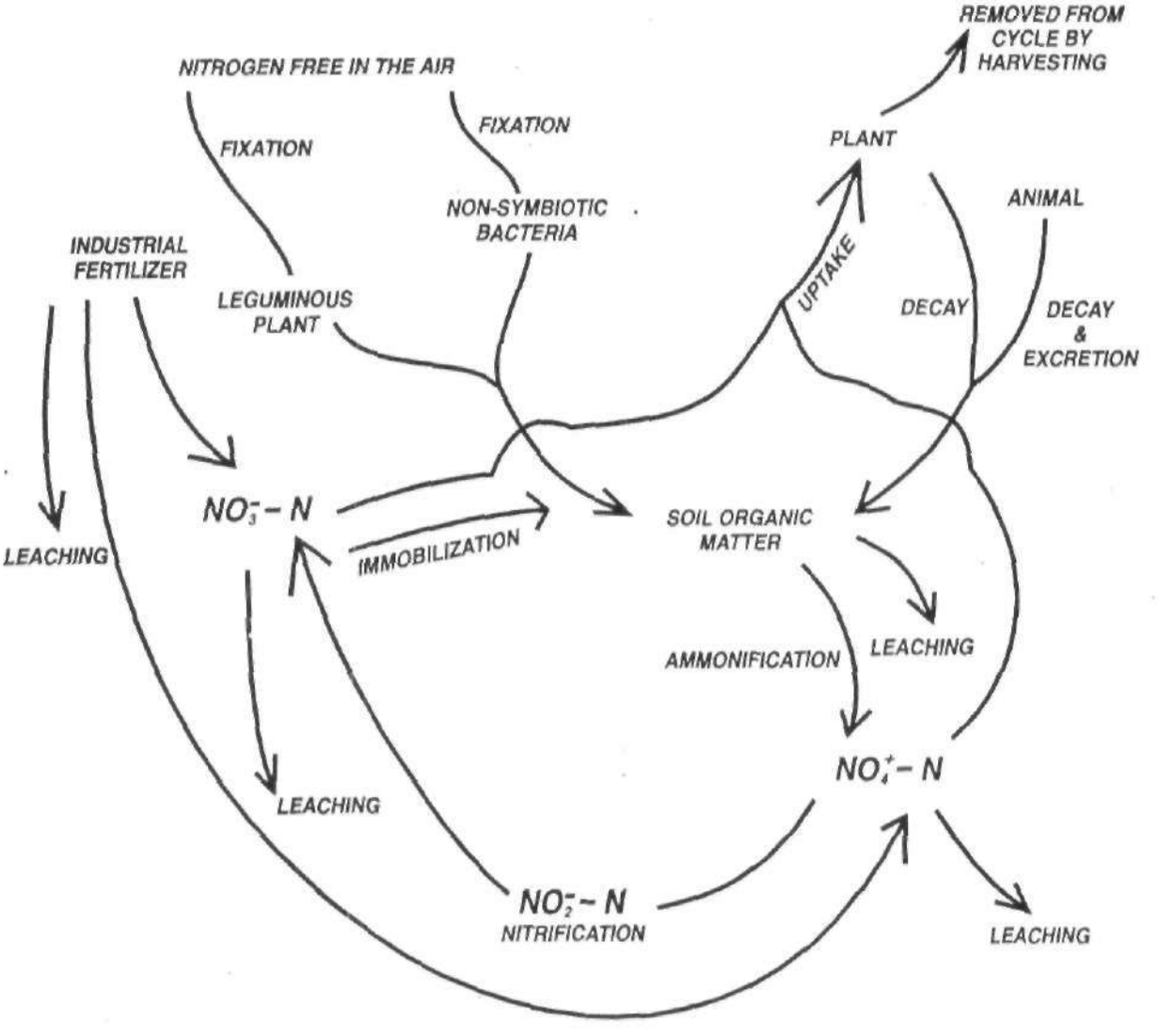

FIGURE 2. 2: MODIFIED SCHEMATIC REPRESENTATION OF NITROGEN CYCLE IN SOIL (SAUCHELLI, FERTILIZER NITROGEN - ITS CHEMISTRY AND TECHNOLOGY, 1964).

A natural process which maintains soil N fertility in rice plantation is biological nitrogen fixation (BNF). The microorganisms responsible for this process in flood water includes photosynthesis bacteria, blue green algae of the flood water, and heterotrophic bacteria associated with rice plant and soil. Since N is a limiting nutrient for rice plantation, strategies for promoting BNF are desirable. To achieve this, Grant *et al.* (1983) studied the effect of alleviating *Ostracoda, Heterocypris luzonensis*, grazing pressure on N_2 - fixing blue green algae by applying crushed neem seeds to paddy flood water and the population of the *crustaceans* that feed on BNF organisms decreased. This led to ten-fold increase in N-fixation activity.

Modification of urea with neem cake has been reported to inhibit the nitrification rate, thus providing available NH_4^+ - N for a longer period (Reddy and Prasad, 1975). Ketkar (1983) carried out an agronomic research on neem cake, neem oil and Karanja cake each blended with urea. The results indicated that application of urea coated with neem cake using coal tar solution gave an average of 0.5 tonnes/ha yield higher than a similar application of uncoated urea on rice (*Oryza sativa*) and sugar cane (*Saccharum officinarum*) crops. The response of urea blended with neem oil on sugar cane yield also gave a good result. Similarly, Amin and Patel (1983) reported that neem cake coated with urea applied at a ratio of 1:5 along with coaltar and kerosine gave 22.8 percent increase in paddy yield of rice compared to the recommended fertilizer practice without neem cake.

2.5 Effect of Organic Wastes on Soil Fertility and Crop Yield

Organic wastes in the form of animal wastes or harvest residues when incorporated into the soil are known to improve crop yield (Abdulrahman, 1989; Tarfa, 1994).

The chemical composition of animal wastes such as cattle manure is influenced by diet, storage and handling conditions (Van Fassen and Van Dijk, 1987). These factors probably account for some of the variation in manure composition reported from different countries. Murwira and Kirchman (1991) have shown that there was no significant difference in the decomposition of aerobically treated manure, regardless of whether they are derived from a low - or high-input system. The fresh manure when added to soil

mineralize little or no N at all, regardless of their origin. This suggests that fresh and aerobically treated manure have a very small N fertilizer effect in the short-term. It was concluded that only the anaerobically decomposed manure would have positive effect on crops in short-term.

In green house and field trials conducted at Samaru, in Nigerian Savanna, Poultry droppings and cow dung increased dry matter yield, height, and girth of maize. Addition of inorganic fertilizers enhance the effect of the amendments on the yield (Abdulrahman, 1989). Addition of cow dung to preincubated cassava peels also increase cocoyam yields (Agbim, 1985). The dry matter yield and nutrient uptake of maize increased as the proportion of cowdung increased when interacted with other organic wastes (Tarfa, 1994).

The two major crop residues in Savanna are harvest residues (straws, stovers, and hulms, etc) and processed residues (groundnut shells, rice husk, oil cakes, etc). About 31.41 million metric tonnes of crop residues were produced in the Nigerian Savanna between 1970 and 1971 cropping season. These residues can either be added to the soil or disposed off through burning (Balasubramanian and Nnadi, 1980). This practice of burning crop residues increase soil pH (Seubert, 1975) thereby increasing effective cation exchange capacity and availability of soil nutrients to plants (Moore and Adetunji, 1966).

2.6 Nitrogen Status of Savanna Soils

Savanna soils are generally low in total nitrogen (N). According to Jones (1973a), percent N ranges from 0.008 to 2.90 with an average value of 0.051 percent. These low values are due to the low level of organic matter in these soils.

The organic matter content of top soils ranged from about 0.5 percent in the Brown and Reddish-Brown soils of the Sahel zone to about 2 percent in Vertisols, Eutrophic Brown and Hydromorphic soils. In the widely occurring Ferruginous soils, an average value of 1.2 percent has been reported in 245 samples (Jones and Wild, 1975). SOM including the microbial biomass is a dynamic nutrient reservoir. Changes in the quantity and mineralization of SOM and soil microbial biomass affect the potential of soil to supply available nitrogen (AN) through alterations in mineralization and immobilization turnover

(Jansson and Persson, 1982). The inherent fertility of a given soil depends largely on the quality and quantity of organic matter in the soil.

Three important factors determine soil N content namely, rainfall, temperature, and aeration. Of these, rainfall is the major factor limiting nitrification since it determines N accumulation and leaching from soil (Fayemi, 1966). According to Wild (1972a), ammonification is reduced at water content below 15 bars and nitrification cease in the dry season. At the start of the rain, there is high ratio of NH_4^+ - N to NO_3^- - N in the soil, which reverses when the soil becomes sufficiently wet to allow nitrification. Thus, excess rainfall leads to denitrification and leaching of N (Kowal and Kassam, 1978).

The N content of the various Savanna soils is attributed to variations in rainfall and clay contents (Jones and Wild, 1975). Due to low annual rainfall of less than 400mm in the Sahel region, the soil N is very low (0.5%) (Kowal and Kassam, 1978).

Activities of nitrobacter and most heterotrophs increase with increase in temperature (Tisdale and Nelson, 1975). It has been reported that maximum ammonification occurs at about 50°C in arid soils of Northern Senegal (Moureaux, 1967). The prolonged exposure of Savanna surface soils to high temperature for most part of the year results in partial desiccation of surface soils (Kowal and Kassam, 1978). Consequently, there is a release of immobilized N locked in dead microbial tissue at the start of the rainy season.

The type of crops previously planted affect AN of Savanna soils, (Wild, 1972a). An experiment carried out on Samaru soil indicated higher AN after previously planting groundnuts than after cotton or sorghum. As an indication of this, yields of maize grown after groundnut were more than those obtained after cotton and sorghum (Jones, 1974). Millet interplanted with cowpea (*Vigna sinensis*) gave a higher crop yield than sole crop millet grown at same plant density. This is due to increased AN from the cowpea (Steele, 1972). It has been suggested that other crops should be planted in rotation with leguminous crops. This will increase AN level in subsequent years through direct N release

from leguminous residue and increases microbial decomposition of soil N reservoir (Pieri, 1990).

Savanna vegetation under fallow system is grass dominated. As these residues are often poor in N, they are prone to immobilization when turned into the soil (Jones, 1973b). This depletion of soil AN might account for the high C:N ration often encountered in the soil (Kadeba, 1978; Jones, 1973a; Hopmans *et al.*, 1980). The pattern of N release from plant residues differ for different plant residues as those with high C:N ratios and lignin contents tend to have slow release of AN (Tian *et al.*, 1992; Hopmans *et al.*, 1980).

2.7 Plant Nitrogen Requirements in Savanna Soils

The mineralization of SOM is of considerable significance in supplying N to crops. Although considerable amounts of AN required by the plants are released in Savanna soils with the onset of the rains, crops planted at this time cannot effectively make use of it (Wild, 1972b; Jones, 1976) because of leaching. Additional fertilization is therefore needed for high N-demanding crops such as cereals (Jones, 1973b; Goldsworthy, 1967).

Inorganic fertilizer, when available can contribute to the intensification and productivity of the cropping systems in the Savanna (Smith *et al.*, 1994; Lele *et al.*, 1989). However, on-farm studies across the Savanna of West Africa indicated 6-fold increase in response of maize yields to the application of N fertilizer.

Among the commercial N fertilizers commonly used in the Savanna, urea and calcium ammonium nitrate (CAN) give good response and are preferred (Lombin, 1988). Relative response of maize to these fertilizers showed that neither of the two is better than the other (Jones, 1973b). Similar results were reported with rain-fed maize and irrigated wheat (Balasubramanian and Singh, 1982).

The major cereal crops grown in the Savanna region (sorghum, millet, wheat and maize) together require an average of about 650,000 - 700,000 metric tonnes of N annually. Another 225,000 metric tonnes are also needed for cotton (Lombin, 1987). This requirement is met by addition of commercial fertilizers and organic wastes. Fertilizer

consumption among the peasant farmers is being hampered by poverty and so the N requirements of most non-leguminous crops are met by inclusion of legumes in the cropping scheme (Lombin, 1988).

In low-input systems, the N demands of crops have to agree with the N supply from native sources in the field (Webeer *et al.*, 1995). The N requirements of crops differ and vary with cultivars, stage of development and environment. The total N uptake is proportional to the dry matter produced by the crop but the proportionality coefficient varies with the crop and cultivar (Kowal and Kassam, 1978).

In a long-term field trial at Samaru in West African Savanna, Goladi (1997) observed a degradative effect of inorganic fertilizer on soil fertility.

2.8 Efficiency of Nitrogen Uptake by Crops in the Savanna

Leaching is one of the major factors affecting the efficiency of N utilization (Jones, 1976). It is rapid due to the generally high intensity of the rainfall. Wild (1972b) reported slow leaching of native soil NO_3^- because of rapid water infilteration through cracks, channels, and macropores while NO_3^- in soil is confined to the micropores. The slow leaching of NO_3^- in Samaru soil has been attributed to rapid percolation of the rainfall during the first half of the rainy session (Jones, 1976). This rapidly percolating water may carry with it up to a quarter of the NO_3^- applied to the tropical but the larger amount of the applied NO_3^- passes through the soil profile down as a slow wave.

Other factors which affect N utilization efficiency by crops are volatilization and denitrification (Lombin, 1988). The loss of N by ammonia volatilization following urea application has been widely reported (Fenn and Kissel, 1973; Ghandi and Pahwal, 1976; Matocha, 1976).

Timing and splitting of N fertilizer application are two inter-related agronomic techniques employed in enhancing the effect of N use in Savanna (Lombin, 1988).

2.9 Kinetic Models for Describing Soil Nitrogen Mineralization

Kinetic modelling (Table 2.1) of net N mineralization observed in laboratory incubation experiments has been used to characterize mineralizable N potential and the added organic residues. Fitting kinetic equations to net N mineralization curves helps to quantify mineralization substrates and the rate at which it is made available for plant use. Simple incubation studies which integrate gross mineralization and immobilization provide an understanding of mineralization mechanism but accurate description requires isotopic tracers to identify specific classes of substrates and mineralization pathways (Ellert and Bettany, 1988).

Simple incubation experiments have been used to study nutrient cycle (Fyles and McGills, 1987; Bonde and Rosewall, 1987). The procedure, however, is not without its short comings, as moisture in the incubation medium may differ from values obtained in the field and the process may change oxidation status, and hence N mineralizable potential. Atmospheric composition may also differ as O_2 is used and CO_2 is released (Ross *et al.*, 1990).

Stanford and Smith (1972) used iterative procedure to fit a logarithm transformed version of the first order model. Others using Stanford and Smith's techniques have reported comparable results (Stanford *et al.*, 1974; Cassman and Munns, 1980) and have improved upon the estimation of the models (Smit, *et al.*, 1980; Talpaz *et al.*, 1981). Griffin and Laine (1983) reported higher values and more variable values for mineralization rate constant than previous studies. However, N mineralization potential has been found to be a poor means of predicting crop yield and N uptake (Lindermann and Cardenas, 1984) but the reason for this assertion was not elucidated.

The concept of single pool of easily mineralizable N does not synchronize with reality, and first order model based on this concept can at times be inferior to empirically determined model as a means of describing soil N mineralization (Broadbent, 1986). This might be the reason why Jones (1984) developed first order equation (Table 2.1) to

accomodate separate pools of easily mineralizable N. The added parameter produced the mineralization flush during the first incubation interval.

TABLE 2.1: SOME KINETIC MODELS FOR DESCRIBING NET NITROGEN MINERALIZATION IN SOILS

MODEL	EQUATION	REFERENCE
First order (n=2)$^{++}$	$N_{ct} = N_o(1-e^{-kt})$	Standford and Smith (1972)
First order (n=3)	$N_{ct} = N_o(1-e^{-kt}) + Ne$	Jones (1984)
Two simultaneous reactions (n=4)	$N_{ct} = N_oF(1-e^{-ht}) + N_o(1-F)(1-e^{-kt})$	Molina *et al.* (1980)
Consecutive reactions (n=3)	$N_{ct} = N_o - N_o(ke^{-ht} - he^{-kt})(k-h)$	Noggle (1985)
Consecutive reactions where h=k (n=2)	$N_{ct} = N_o - N_o e^{-kt}(kt + 1)$	Noggle (1985)
Gompertz (n=3)	$N_{ct} = N_o e^{he^{-kt}} - N_o e^{h}$	France and Thornley (1984)
Mixed order (n=3)	$N_{ct} = N_o(1-e^{-kt-0.5ht^2})$	Brunner and Focht (1984)

where N_{ct} = cumulative N mineralized at time t (mg/kg),

t = time (weeks),

N_o = potentially mineralizable N (mg/kg) at t = 0

Ne = easily mineralizable (N mg/kg),

N_oF = easily mineralizable subfraction

$N_o(1-F)$ = slow mineralizable subfraction, h and k are proportionality constants per week and are specific for the model in which they appear.

++n = number of adjustable parameters in the model

Nitrogen mineralization can be viewed as the decomposition of two or more compounds with varying mineralization rates. Molina *et al.*, (1980) and Vanotti *et al.* (1995) suggested that parameters based on summation of two or more exponentials for some soils would fit better than the first order model (Table 2.1). The model separates the N_o into a rapidly mineralizable subfraction (N_oF) and a slow mineralizable subfraction $N_o(1-F)$. Mineralization for the fast and slow mineralizable organic fractions is described by first order kinetics with rate constants h and k respectively.

Consecutive reactions, Gompertz and mixed order models have also been used to describe mineralization curves which had a lag during some portions of the incubation period (Ellert and Bettany, 1988) because of the sinuous pattern of N released which showed a lag and subsequent increase in the mineralization rates which are not in agreement with the decreasing rates specified in the first order model. Similar lags were noted in cumulative mineralization curves, but the lags were unaccounted for in kinetic models (Stanford and Smith, 1972; Chae and Tabatabai, 1986; Fyles and McGills, 1987). Therefore, Brunner and Focht (1984) developed a sigmoidal mineralization pathway which are characteristic of resistant organic compounds. The model conceptualizes that a single substrate pool is mineralized via a first order mineralization pathway in simultaneous with second order mineralization pathway. According to second order mineralization pathway, mineralization process depends on biomass and substrate concentration. The disappearance of substrate is controlled by a mixed order rate constant which is distributed between k ($week^{-1}$) for first order mineralization and time-h ($week^{-2}$) for second order mineralization.

Consecutive reactions describe a process of proceeding from reactants to products through an intermediate constituents. Conversion of reactant to intermediate and product follows first order kinetics with rate constants h and k, respectively. A model is derived from the differential rate equation where values of h and k are similar.

Gompertz model is an S-shaped growth function (Jowet *et al.*, 1974; Draper and Smith, 1981). It suggests that mineralization is proportional to the cumulative nutrient

release and the mineralization rate increases in the early stages of incubation. However, overtime, the proportionality factor decreases thus reflecting a decrease in the effectiveness of the mineralization processes because of exhaustion of the mineralizable substrate (France and Thornley, 1984).

Nitrogen mineralization is influenced by temperature, soil moisture, space, O_2, pH, ion activity and availability of substrate (Stanford and Epstein, 1974; Grant *et al.*, 1993; Cassman and Munns, 1980). Tabatabai and Khafaji (1980) have shown that SOM mineralization at 35°C was greater than at 20°C. Hence, a detailed description of mineralization process in quantitative terms require equations with many variables some of which are not readily measured or vary in unpredictable ways. Such models often involve some assumptions. Therefore, an alternative way of describing net N mineralization is to use empirical models that describe the process with considerable accuracy (Broadbent, 1986).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Sampling of Neem Seeds

Mature fruits were obtained from neem trees at Samaru - Zaria. Samaru is situated in the Northern Guinea Savanna vegetation zone with a mean annual rainfall of 1050mm confined to a single 5 months rainy season from May to September (Kowal and Knabe, 1972).

The fruits were depulped and the seeds dried in an oven at 45°C for 24 hours. The kernels were removed from the seed coat and then stored in air-tight glass bottles. These were later crushed, ground to pass through 3mm stainless steel sieve and stored in a polythene.

3.2 Chemicals

All chemicals used were of analytical grade unless otherwise stated.

3.3 Determination of Crude Oil Content of Neem Seeds (Soxhlet Extraction Method, ACOCS, 1942)

The ground seed sample (80g) was weighed into a preweighed fat-free thimble. About 350cm^3 of n-hexane was poured into a previously weighed round bottom flask containing boiling chips and soxhlet extractor set-up. The extraction was carried out for about $4^1/_2$ hours after which the n-hexane was distilled off leaving the oil in the flask in an oven set at 70°C to constant weight. The percent oil was then calculated as follows:

$$\% \text{ oil} = \frac{\text{weight of oil (g)}}{\text{weight of seed sample (g)}} \times 100$$

3.4 Preparation of Neem Cake

The cake obtained after oil extraction as above was oven dried at 40°C for 24 hours to remove the solvent (n-hexane). It was later analysed for: percent moisture, total N and total P.

3.5 Determination of Moistute Content of Neem Cake (AOAC, 1980)

About 2.0g of the sample was weighed into a clean, dried and preweighed crucible. The sample was dried in an oven at 70°C, until constant weight was obtained. Triplicate determinations were carried out on the sample. The moisture content was calculated as the loss in weight of the sample on drying.

$$\% \text{ moisture content} = \frac{weight\ of\ moisture\ (g)}{weight\ of\ sample\ (g)} \times 100$$

3.6 Soil Sampling, Treatment and Determination of some Soil Properties

The soil sample was collected from the surrounding of the Gymnasium of Ahmadu Bello University, Samaru - Zaria in February, 1996. The plot had been under fallow condition for several years except the previous year in which it was cropped with cowpea.

Soil samples collected at randomised points at 0-15cm depth, were bulked and mixed thoroughly. The clods were broken using pestle and mortar, and sieved through 2mm stainless steel sieve. Subsamples were subsequently taken for characterization of the soil. The soil was later used for laboratory incubation and green house studies.

3.6.1 Determination of Organic Carbon in the Soil (Walkley-Black, 1934)

Reagents

(1) Potassium dichromate ($K_2Cr_2O_7$), M/6-: 49.04g oven-dried $K_2Cr_2O_7$ was dissolved in distilled water and was made up to mark in a litre volumetric flask.

(2) 98% w/w concentrated sulphuric acid (H_2SO_4)

(3) Ammonium ferrous sulphate hexahydrate [$(NH_4)_2SO_4.FeSO_4.6H_2O$], 0.5m -: 196g of the reagent was dissolved in distilled water in to which $10cm^3$ of concentrated H_2SO_4 had been added. The solution was well agitated to dissolve the salt and then made up to mark in 1 litre volumetric flask.

(4) Ferroin Indicator -: This was prepared by dissolving 7.425g of O-phenanthroline monohydrate and 3.475g of ferrous tetraoxosulphate (VI) heptahydrate ($FeSO_4.7H_2O$) in distilled water. This solution was made up to mark in $500cm^3$ volumetric flask.

Procedure

A gram of soil was weighed into 250cm^3 Erlenmeyer flask, 5cm^3 of M/6 $K_2Cr_2O_7$ was added and the flask swirled gently to disperse the soil. Concentrated H_2SO_4 (10cm^3) was rapidly added and swirled for a minute. After 30 minutes, 100cm^3 of distilled water was added, and the solution allowed to cool. The resulting solution was titrated against $(NH_4)_2SO_4.FeSO_4.6H_2O$ after the addition of 3 drops of ferroin indicator. The colour changed from blue to green to dark green and finally to red. Blank determination was also carried out. Triplicate determinations were made. Percent organic carbon was calculated as:

$$\% \text{ organic carbon} = \frac{blank\ titre - actual\ titre \times 0.3 \times M}{weight\ of\ soil\ taken}$$

where F = correction factor = 1.33 and M = concentration of $(NH_4)_2SO_4.FeSO_4.6H_2O$

3.6.2 Determination of Soil Water Holding Capacity

The base of a disposable cup was perforated with office pin and weighed. Fifty grams of soil were put into it and enough water to saturate the soil. The suspension was left to stand for about 30 hours to allow the water to drain through the basal pores of the cup. The cup and the moist soil were latter weighed to determine the soil water holding capacity. Triplicate determinations were made. The percent soil water holding capacity was calculated as:

$$\% \text{ water holding capacity} = \frac{weight\ of\ moisture\ in\ the}{weight\ of\ dried\ soil} \times 100$$

3.6.3 Determination of Soil pH

Reagents/Materials

(1) 0.01M calcium chloride ($CaCl_2$)

(2) pH7 standard buffer solution

(3) pH meter Model 290MK 2

Procedure

To 10g of soil sample was added 10cm^3 of distilled water in a 50cm^3 beaker. The suspension was stirred for 30 minutes and was allowed to stand for 3 minutes. The pH of the suspension was measured with the pH meter after pre-caliberating it with buffer solution. The procedure was repeated using 0.01M $CaCl_2.2H_2O$.

3.6.4 Determination of Soil Available Nitrogen (Bremner, 1965)

Reagents

(1) 2M potassium chloride (KCl)

(2) 2% w/w boric acid (H_3BO_3)

(3) 0.005M H_2SO_4 -: 0.27cm^3 of concentrated H_2SO_4 (98% w/w) was added to about 100cm^3 of distilled water. The resulting solution was made up to mark in a litre volumetric flask.

(4) Mixed indicator-: 0.2g of methyl blue was dissolved in 80cm^3 ethanol. Methyl red (0.4g) was also dissolved in 80cm^3 ethanol. Both indicators were then transferred into a 200cm^3 volumetric flask which was then made up to mark with ethanol.

(5) A carbonate free heavy magnessium oxide (MgO)

(6) Devarda's alloy

(7) 2% w/w sulphamic acid (NH_2SO_3H). The solution was stored in a refrigerator after preparation.

Procedures

Three grams of soil was weighed into a 250cm^3 plastic bottle and 30cm^3 of 2M KCl was added. The bottle was stoppered and shaken on a mechanical shaker for an hour. The suspension was latter centrifuged to obtain a clear solution. If the KCl extract could not be analysed after extraction (within 24 hours), it was stored in a refrigerator to avoid decomposition. The KCl extract was distilled as follows:

(a) NH_4^+ - N -: 10cm^3 of 2% H_3BO_3 solution and 2 drops of mixed indicator solution were added to a 50cm^3 Erlenmeyer flask which was placed under the condenser of the steam distiller. The end of the condenser was about 1cm below the surface of H_3BO_3 solution. An aliquot (10cm^3) of the KCl extract of the soil was pipetted into

a distillation flask, and 0.5g of MgO added. The extract was distilled into H_3BO_3 solution until about 30-50cm^3 of the the distillate was collected in the receiver flask. The amount of NH_4^+ - N in the distillate was determined by titration with 0.005M H_2SO_4. The colour change at the end point was from green to pink.

(b) NO_3^- - N -: To the same extract used for NH_4^+ - N distillation, were added 0.2g of devarda's alloy and 1cm^3 of 2% sulphamic acid. Distillation was carried out over another 10cm^3 of 2% H_3BO_3 solution containing 2 drops indicator. The distillate was again titrated against 0.005M H_2SO_4 to end point. Triplicate determination were made.

Calculation

$$\text{Available N (mg/kg)} = \frac{a_1 \times a_3 \times 14 \times M \times 2}{a_2 \times b}$$

where a_1 = volume of KCl extract (cm^3), a_2 = volume of aliquot taken (cm^3), a_3 = volume of acid used for titration (cm^3), b = weight of soil sample (g), and M = molarity of the acid

3.6.5 Determination of Total Nitrogen in Soil or other Materials (AOAC, 1980)

Reagents

(1) 2% w/v boric acid (H_3BO_3)

(2) 10M sodium hydroxide (NaOH) solution

(3) 98% w/w concentrated H_2SO_4

(4) Catalyst -: 500g of anhydrous sodium sulphate (Na_2SO_4), 50g of hydrated copper sulphate ($CuSO_4.5H_2O$), and 0.5g of selenium oxide (SeO_2) were mixed and grinded together.

(5) Mixed indicators (same as for soil available N determination)

(6) 0.005M H_2SO_4

Procedure

To 1g of soil or cake (0.2g of shoot or root sample) were added 5g of catalyst (about 1g for shoot or root sample) and 10cm^3 of concentrated H_2SO_4 in a digestion tube.

It was heated continuously on low heat until frothing has ceased. The heating was increased until the digest became clear. On cooling the digest was quantitatively transferred into a 100cm^3 volumetric flask. The tube was rinsed several times with distilled water, each rinsed portion transferred in to the same flask and was made to mark with distilled water (all the sand particles were retained in the original bottle because sand causes severe bumbing, i.e. for soil digest).

The digest solution (10cm^3) was pipetted into distillation flask and 10cm^3 of 10M NaOH added. The contents of the flask was distilled into 10cm^3 H_3BO_3 containing 2 drops of mixed indicators, until the distillate was about 40cm^3. This was titrated against 0.005M H_2SO_4 to end point (green to pink). A blank determination was made. Triplicate determination were made for soil and neem cake.

Calculation

$$\text{Total N (mg/kg sample)} = \frac{a_3 - a_1 \times 2 \times 14 \times M}{a_2 \cdot 6}$$

where a_1 = volume of digest solution (cm^3)

a_2 = volume of aliquot taken

a_3 = volume of acid used for titration

b = weight of sample

M = molarity of H_2SO_4

The total N (mg/kg) of the sample was converted to percentage and percent protein obtained by multiplying the percent N by a conversion factor of 6.25.

3.6.6 Determination of Soil Available Phosphorus (Bray and Kurtz, 1945)

Reagents

(1) 1M ammonium fluoride (NH_4F)

(2) 0.5M hydrochloric acd (HCl)

(3) Extracting solution-: 15cm^3 of 1M NH_4F and 25cm^3 of 0.5M HCl were mixed in a 500cm^3 volumetric flask and made up to mark with distilled water. This gave a solution of 0.03M NH_4F and 0.025M HCl.

(4) 40% w/v stannous chloride dihydrate ($SnCl_2.2H_2O$):- 10g of the reagent was dissolved in 25cm^3 of concentrated HCl. The stock solution was kept in a black, glass stoppered bottle and stored in a refrigerator. When needed dilute solution (0.4% w/v) was prepared by mixing 1cm^3 of stock solution with 333cm^3 of distilled water.

(5) 10M HCl

(6) 1.5% w/v ammonium paramolybdate [$(NH_4)_6Mo_7O_{24}.4H_2O$]-: 15g of the reagent was dissolved in 350cm^3 of distilled water, 350cm^3 of 10M HCl was added slowly with stirring. The resulting solution was cooled to room temperature and made up to mark in a litre volumetric flask. This was stoppered in a dark glass bottle.

(7) 100ppm standard phosphate solution:- The stock solution was prepared by dissolving 0.4393g of oven-dried potassiumdihydrogen phosphate (KH_2PO_4) in distilled water and mixing up to mark in 500cm^3 volumetric flask. Working phosphorus standard solution (5ppm P) was then prepared by diluting 5cm^3 of the stock solution up to 100cm^3 in a volumetric flask with distilled water. It was stored in a dark bottle and later kept in a refrigerator. A set of standard P solutions containing 0, 0.1, 0.2, 0.4, 0.6, 0.8 and 1.0 ppm P were prepared from this.

Procedure

One gram of soil was weighed into centrifuge tube containing 7cm^3 of the extracting solution. This was shaken for 2 minutes on a mechanical shaker and then centrifuged to obtain a clear solution. The supernatant was decanted into a vial. Ammonium paramolybdate solution (2cm^3) and 1cm^3 of $SnCl_2$ dilute solution were added to it. The colour that developed was measured after 10 minutes but not later than 15 minutes on a Bosch and Lomb Spectronic 20 Spectrophotometer at 660nm. Triplicate determinations were made.

Calculation

$$P\ (mg/kg) = \frac{b \times solution\ volume \times 10^3}{aliquot\ taken \times weight\ of\ soil\ (g)}$$

where b = mg P obtained for the sample extract from standard curve

3.6.7 Determination of Total Phosphorus in Soil or Plant Material (Murphy and Riley, 1962)

Reagents

(1) 4M NaOH

(2) 4% w/v ammonium paramolybdate solution-: 40g of the salt was dissolved in distilled water and made up to mark in a litre volumetric flask.

(3) 2.64% w/v ascorbic acid solution-: 26.4g of the acid was dissolved with distilled water and made up to mark in a litre volumetric flask.

(4) 0.29% w/v antimony potassium tartrate solution-: 1.45g of the reagent was dissolved in distilled water and made up to mark in a 500cm^3 volumetric flask.

(5) 2.5M H_2SO_4

(6) 0.25M H_2SO_4

(7) Developing reagent-: 50cm^3 of 2.5M H_2SO_4, 15cm^3 of the ammonium paramolybdate solution, 10cm^3 ascorbic acid solution, and 5cm^3 of antimony potassium tartrate solution were mixed in a 100cm^3 volumetric flask. The resulting solution was made up to the mark with distilled water and stored in a refrigerator.

(8) 0.25% w/v paranitrophenol indicator

(9) Standard phosphorus and working phosphorus standard solution as prepared in 3.6.6.

Procedure

The digested sample (2cm^3) obtained from 3.6.5 was pipetted into 100cm^3 volumetric flask. Two drops of 0.25% paranitrophenol were added and the pH was adjusted with 4M NaOH and 0.25M H_2SO_4 until the colour changed from orange to colourless. Developing reagent (8cm^3) was added and the mixture made up to mark with distilled water. The flask was shaken and left to stand for 10 minutes. A blank was

prepared and the absorbance was read at 712nm on Bosch and Lomb Spectronic 20 Spectrophotometer. Triplicate determination were made.

Calculation

$$\text{Total P (mg/kg)} = \frac{b \times \text{volume solution (cm}^3) \times 10^3}{\text{sample aliquot (cm}^3) \times \text{sample weight}}$$

where b = mg P obtained for the sample from the standard curve.

3.7 Laboratory Incubation Studies

Two grams of the cake were uniformly mixed with 100g of soil sample and placed in a Buckner funnel whose base was covered with nylon screen. Distilled water was added to the mixture to obtain about 80% soil water holding capacity. The content of the funnel was covered with nylon screen to reduce dispersion during the extraction process. The set-up was incubated at laboratory temperature and the moisture content was maintained by periodic addition of distilled water.

The soil was extracted with 2M KCl on weekly basis up to the 6th week and then forthnightly until the 14th week of incubation. The extractions were carried out with 200cm^3 KCl at the first two weeks of incubation and with 100cm^3 of 2M KCl for the remaining periods. The pH of the soil extract was taken. The reduction in volume was to produce a concentrated solution for direct measurement and to reduce the amount of organic N extracted from the soil treatment (Smith *et al*., 1980). To account for native soil N transformation, control experiment was mounted in a similar way without the neem cake. AN was determined following the proceedure described in 3.6.4. Triplicate determinations were made.

3.8 Green House Trial of Neem Cake and Urea

A green house assessment of neem cake (C), urea (U) and a mixture of urea and neem cake (C x U) was carried out at the Institute for Agricultural Research, Ahmadu Bello University, Samaru - Zaria.

3.8.1 Treatments and Their Combinations

The standard application rate of N fertillizer for maize is 120kgN/ha. If a hectare of soil at Samaru is assumed to contain 1,950,000kg of soil, then 3 kg of soil will require $\frac{120kg}{1,950,000kg}$ x 3kg N = 0.1846 x 10^{-3}kg N = 184.6mg N

3.8.1.1 Calculation of the Amount of Nitrogen Required by 3kg of Soil Using Urea

Since 120kgN/ha require 184.6mg N per 3kg of soil and 100g of urea contains 46000mg N. 184.6mg N will be supplied by $\frac{184.6mg \times 100}{46000mg}g$ = 0.4013g

3.8.1.2 Calculation of the Amount of Nitrogen Required by 3kg of Soil Using Neem Cake

From the chemical analysis of neem cake, 1g of cake contains 69.3mg N. Therefore, 184.6mg N will be supplied by $\frac{184.6}{69.3}$ g = 2.6637g

3.8.1.3 Application of the Treatments

Treatments were applied as follows:

(1) 40kg, 80kg and 120kg N/ha of urea.

(2) 80kg, 120kg, 240kg, 480kg and 960kg N/ha of neem cake

(3) Combinations of neem cake and urea at: C_{80} x U_{40}, C_{80} x U_{80}, C_{120} x U_{40}, C_{120} x U_{80}, C_{240} x U_{40}, C_{240} x U_{80}, C_{480} x U_{40}, C_{480} x U_{80}, C_{960} x U_{40}, and C_{960} x U_{80}, kg N/ha.

(4) Control experiment. This consisted of a pot without neem cake, urea or combination of both.

These gave 19 different treatments which were triplicated and completely randomised to give a total of 57 pots. Three kilograms of soil were weighed into each pot and mixed uniformly with each of the treatment.

The soil in the pots were maintained at field capacity through regular watering with distilled water. Drained water in the receivers were returned into the pots. The pots were left to incubate for 2 weeks for equilibration purpose.

3.8.2 Planting

At the end of incubation period, 6 seeds of maize *(Zea mays L.)* TZSER - W were planted in each pot. Seven days after planting, the germinated seeds were thinned to 3 stands per pot. All the pots were maintained at field capacity throughout the experimental period by regular watering with distilled water. Observations were daily made on the plants for symptoms of nutrient deficiency and to keep the pest under check.

3.8.3 Harvesting

3.8.3.1 First Cropping

After 6 weeks of growth in the green house, the plants were harvested. Each pot was harvested by cutting the plants just above the soil surface. The harvests were washed thoroughly with tap water and then rinsed with distilled water. They were later stored in labelled envelopes, and were dried to constant weight in an oven set at 60°C. The roots were harvested by emptying the content into a large plastic bowl and the roots removed. The harvested roots were treated in the same way as the shoot. The dried samples were ground with a stainless steel mill in readiness for chemical analysis.

The following parameters were determined on the soil subsamples and the harvest:

(a) Available P of the soil after the plants were harvested

(b) Nitrogen uptake of the roots and shoots

(c) pH of the soil in distilled water

(d) Dry matter yield of the shoots and roots

3.8.3.2 Second Cropping

The remaining soils were uniformly remixed with P (KH_2PO_4) at 60kg P/ha for each of the pot. The soils were put back into each of the pots, watered to field capacity with distilled water and cropped for second time. After 6 weeks the shoots and the roots were harvested. All the parameters determined at the end of the first cropping were repeated except for soil available P.

3.8.3.3 Third Cropping

The soil in the pots were planted with maize after remixing with KH_2PO_4 applied at 60kg P/ha. After 6 weeks of growth, the roots and shoots were harvested. The post harvest parameters determined at the end of second harvest were repeated again.

3.9 Statistical Analysis

3.9.1 Laboratory Incubation Studies

Classical first order and first order E equation models were used to describe the N mineralization from soil incubated with neem cake. Non-linear iterative procedures were also used to estimate potentially mineralizable N (No), easily mineralizable N (Ne) and mineralization rate constants (SAS Institute Inc., 1985).

The coefficient of multiple determinations (R^2), and the root mean square error (RMSE) were computed to assess the goodness-of-fit statistics of the two forms of first order rate equation. Model with higher R^2 and lower RMSE indicate that the model fits a particular mineralization pattern better than the model with lower R^2 and higher RMSE.

3.9.2. Green House Studies

All the data from green house studies were subjected to analysis of variance (ANOVA) using System Analytical Statistics (SAS) at Data Processing Unit of Institute for Agricultural Research, Ahmadu Bello University, Samaru - Zaria. Means separation were achieved by Duncan multiple range test (DMRT).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Chemical Composition of the Neem Cake

Chemical composition shown in Table 4.1 indicated that the neem cake has a mean crude protein of 43.13 ± 0.1% . This result is consistent with the values reported by Goje (1992) but higher than the 37.5% reported by Om Prakash *et al.* (1953), and 13.25% by the NRC (1992). The percent crude protein in neem cake depends on the amount of oil left in the cake and probably the extraction method. The consistency between our data and that of Goje (1992) might be due to the similarity of extraction techniques utilizing soxhlet extraction procedure.

The moisture content of neem cake is about 5.00 ± 0.02%. This is lower than the 9.2% reported by Goje (1992). Variation in the moisture content might be due to differences in the ripeness and the length of storage period (Addy, 1978). Reduction in moisture content reduces the rate of biochemical changes in the seed and inhibit the growth of micro organisms.

Neem seed can be regarded as a good source of oil. The oil content of 48.00 ± 0.05% obtained in this study is comparable to the range (40-45%) reported by Mitra (1963) and Goje (1992).

The P content of the neem cake was 0.86 ± 0.02%, while Reddy and Prasad (1975) and Goje (1992) reported 0.52% and 0.65% respectively. The higher P content of the neem cake used in this study might be due to varietal differences of the neem tree.

4.2 Physicochemical Properties of the Soil

The physicochemical properties of the soil are shown in Table 4.2. The soil has low organic matter and total N. Similarly, the available P is low. The low level of total N is a reflection of low organic matter status, a major source of N in agricultural soils without inorganic fertilizer amendment. Forest soils under cultivation in tropical region have the

following compositions: 1.44%, 0.13% and 2.5% organic carbon, total N and SOM respectively (FMOANR, 1990).

TABLE 4.1: CHEMICAL COMPOSITION OF THE NEEM CAKE AS A PERCENTAGE OF DRY MATTER

Crude protein	43.13 ± 0.10
Nitrogen	0.90 ± 0.10
Moisture	5.00 ± 0.02
Phosphorus	0.86 ± 0.02

TABLE 4.2: PHYSICOCHEMICAL PROPERTIES OF THE SOIL

Total N (mg/g)	0.30 ± 0.01
Available N (mg/g)	0.14 ± 0.02
Total P (mg/g)	0.15 ± 0.05
Available P (mg/kg)	2.77 ± 0.04
Organic C (%)	0.51 ± 0.06
Water holding capacity (%)	31.00 ± 0.04
pH (1:2, H_2O)	5.30 ± 0.1
pH (1:2, $CaCl_2$)	4.30 ± 0.1

4.3 Nitrogen Mineralization Patterns of Neem Cake

The cumulative amount of different forms of N mineralized from laboratory incubation studies are as shown in Figures 4.1, 4.2 and 4.3. The cumulative net N mineralized and cumulative NH_4^+ - N released indicated large initial release of inorganic N during the first 6 weeks. The initial flush might be attributed to high organic substrate availability, and microbial activity from the cake. After 6 weeks, the mineralization rate decreased possibly due to decrease in the organic substrate. This decrease in mineralization rate after a given period is consistent with the findings of Jansson (1963). The observed increase in NO_3^- - N concentration throughout the incubation period can be attributed to substrate availability (NH_4^+ - N) or size of the nitrifying bacteria.

A plot of change in pH against weeks of incubation is shown in Fig. 4.4. The graph indicated that there was no change in pH during the incubation period. This was in agreement with the report made by Standard and Smith (1972) that pH of soil is not affected by incubation.

4.3.1 Kinetics of Cumulative NH_4^+ - N Released in the Soil Incubated with Neem Cake

The mineralization pathway of organic N to form NH_4^+ - N can be represented by equation (1) known as ammonification process.

$$\text{Organic N} \xrightarrow[slow]{non-specialized\ organisms} NH_4^+ \text{ -} \qquad \text{----------(1)}$$

The rate of mineralization is proportional to the amount of potentially mineralizable N.

$$\frac{-d[organic]}{dt} = k[NH_4^+] \qquad \text{----------(2)}$$

After integration at time t = 0, the expression can be reorganised into 2 useful forms.

$$\ln ([NH_4^+]/_{[organic\text{ - }N]}) = -kt \qquad \text{----------(3)}$$

$$[NH_4^+] = [organic\text{ - }N](1 - e^{-kt}) \qquad \text{----------(4)}$$

Equation (4) is the first order rate equation similar to the one given in Table 2.1.

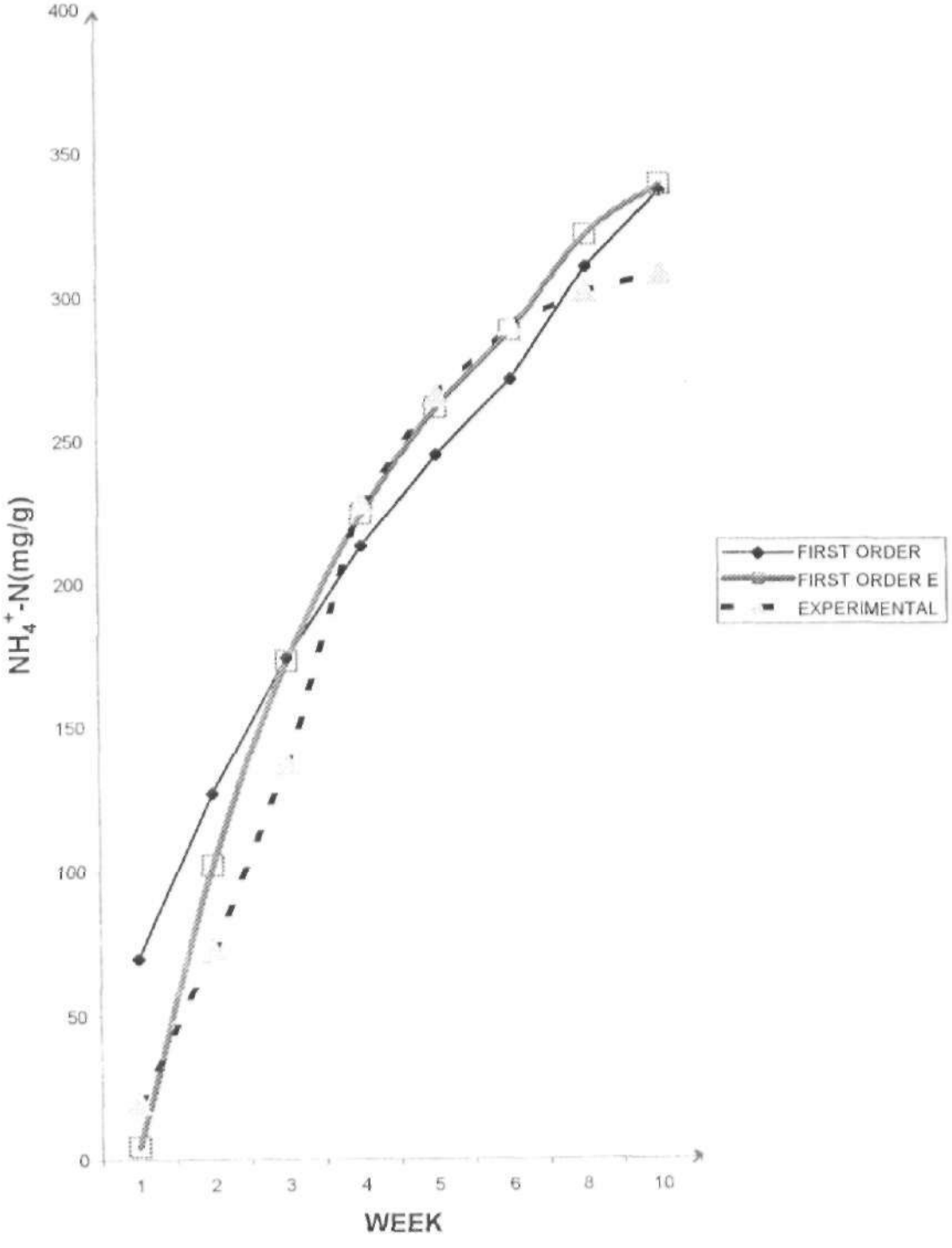

FIGURE 4.1: COMPARISON OF THEORETICAL AND EXPERIMENTAL CURVES OF CUMULATIVE NH_4^+ - N RELEASED FROM THE SOIL INCUBATED WITH NEEM CAKE

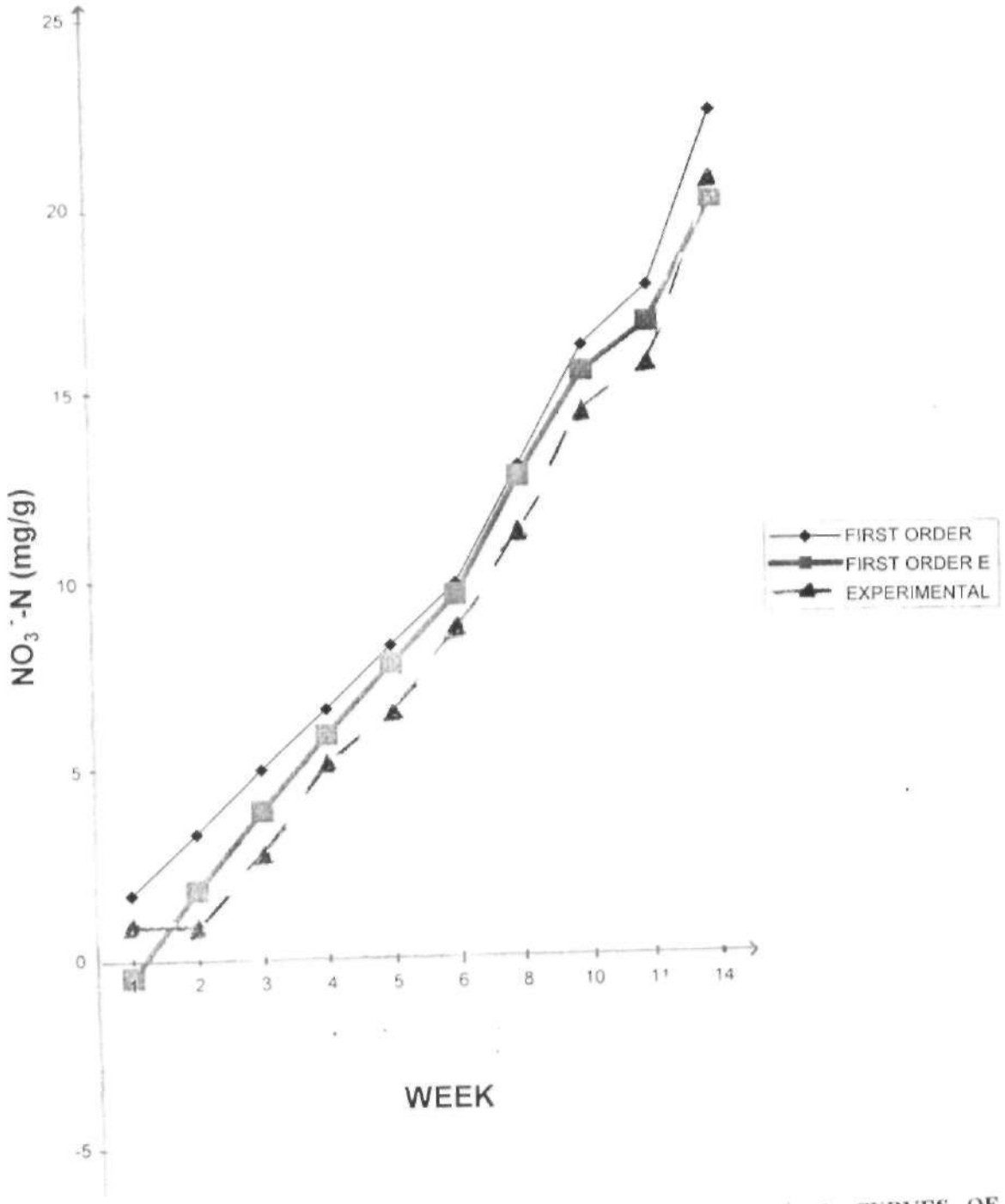

FIGURE 4.2: COMPARISON OF THEORETICAL AND EXPERIMENTAL CURVES OF CUMULATIVE NO_3^- - N RELEASED FROM THE SOIL INCUBATED WITH NEEM CAKE

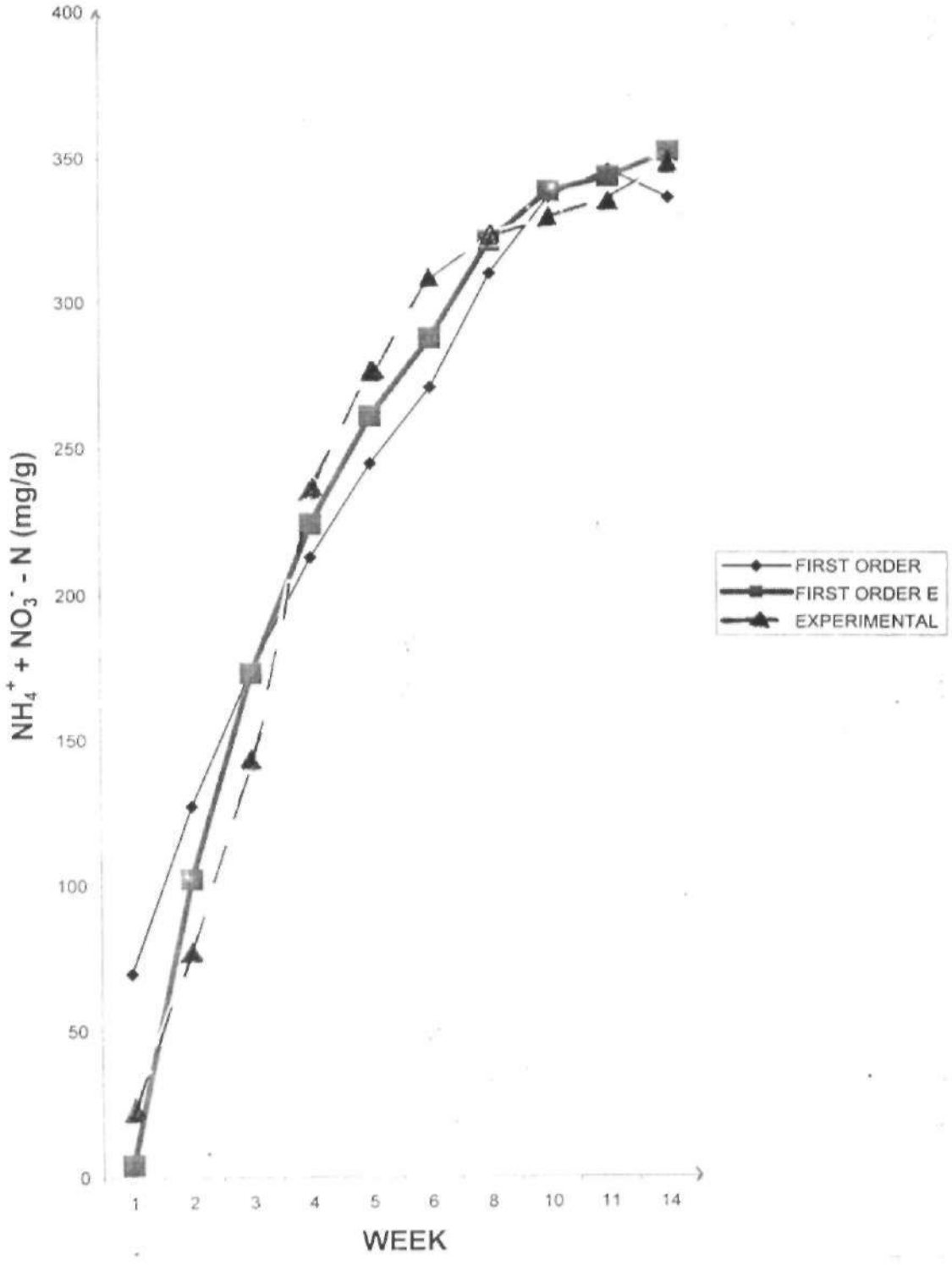

FIGURE 4.3: COMPARISON OF THEORETICAL AND EXPERIMENTAL CURVES OF CUMULATIVE NET NITROGEN ($NH_4^+ + NO_3^-$) RELEASED FROM THE SOIL INCUBATED WITH NEEM CAKE

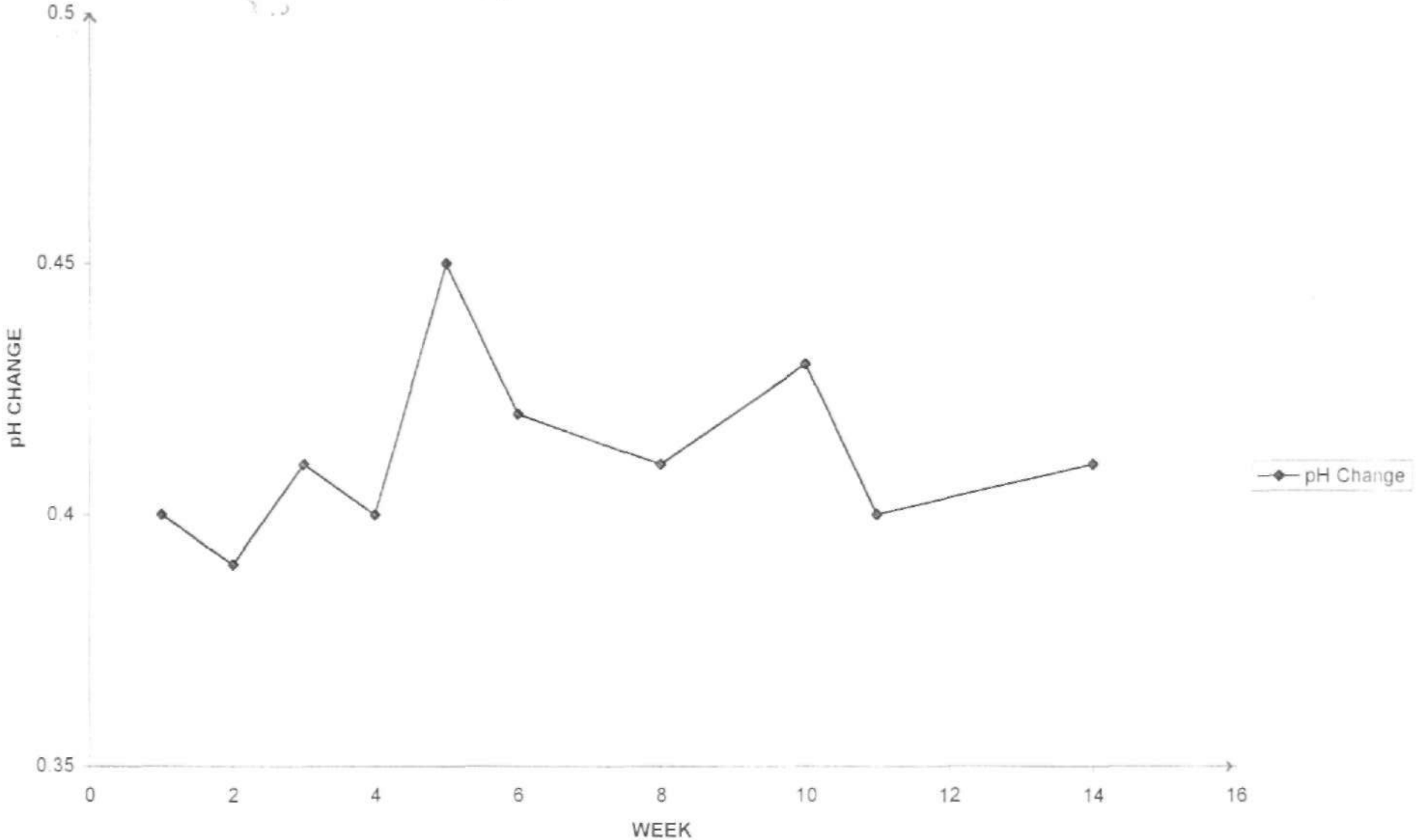

FIG. 4.4: SOIL EXTRACT pH CHANGE AGAINST INCUBATION PERIOD OF SOIL AND NEEM CAKE.

Jones (1984) modified the first order rate equation by including a term which takes in to account the readily mineralizable N pool in organic residues. Hence, the NH_4^+ - N released according to first order E model can be represented by:

$$[NH_4^+] = [\text{organic N}](1 - e^{kt}) + Ne \quad \text{---------- (5)}$$

The amount of NH_4^+ - N released were well described by both first order and the modified first order as presented in Table 4.3. However, the slight improvement in R^2 value of the modified first order can be explained by the inclusion of Ne which describes the easily mineralizable N pool not accounted for by the classical first order rate equation. The negative Ne obtained (Table 4.3) accommodated the initial lag in mineralization process. The cause of the lag might be due to low enzymatic activity of the decomposition process at the initial stage. Comparison of the graph obtained by plotting theoretical and experimental cumulative NH_4^+ released has shown improvement in the use of first order E model over unmodified first order model (Fig. 4.1).

4.3.2 Kinetics of Cumulative NO_3^- N Released in the Soil Incubated with Neem Cake

The nitrification process is represented by equation (6) and (7)

$$2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 2H_2O + 4H^+ \quad \text{----------(6)}$$

$$2NO_2^- + O_2 \rightarrow 2NO_3^- \quad \text{---------- (7)}$$

Therefore, the classical first order model for NO_3^- released is given by equation (8) and the first order E model can be represented by equation (9).

$$[NO_3^-] = [NH_4^+](1 - e^{-kt}) \quad \text{---------- (8)}$$

$$[NO_3^-] = [NH_4^+](1 - e^{-kt}) + Ne \quad \text{---------- (9)}$$

The goodness of fit statistics as shown in Table 5 indicates that there is an improvement in the first order E model which contain a term (Ne) that accommodates easily mineralizable N.

As indicated in Table 4.4, first order E is better for describing cumulative NO_3^- released in the treated incubated soil than simple first order equation. Comparison of

theoretical and experimental curves also indicates improvement in the use of first order E over classical first order model (Fig. 4.2).

TABLE 4.3: GOODNESS-OF-FIT STATISTICS AND PARAMETERS ESTIMATE FOR COMPARING THE KINETIC MODELS FITTED INTO CUMULATIVE NH_4^+ - N DATA FROM SOIL INCUBATED WITH NEEM CAKE

Model	R^2	RMSE	No	Ne	k
First order	0.819	47.854	326		0.234
First order E	0.881	41.413	449	-147	0.401

TABLE 4.4: GOODNESS-OF-FIT STATISTICS AND PARAMETERS ESTIMATE FOR COMPARING THE KINETIC MODELS FITTED INTO CUMULATIVE NO_3^- - N DATA FROM SOIL INCUBATED WITH NEEM CAKE

Model	R^2	RMSE	No	Ne	k
First order	0.938	1.84	240		0.007
First order E	0.955	1.670	38.5	-2.88	0.065

4.3.3 Kinetics of Cumulative Nitrogen (NH_4^+ + NO_3^-) Released in Soil Incubated with Neem Cake

The goodness-of-fit statistics of cumulative N released in the incubated soil is shown in Table 4.5. The mineralization rate constants of first order model and first order E model are 0.196 and 0.324 per week respectively. The mineralization rate constant for a wide variety of soils reported by other workers (Mary and Remy, 1979; Stanford amd Smith, 1972; Oyanedel and Rodriguez, 1977) ranged between 0.027 - 0.058 per week at 25 - 35°C. The differences in the values of rate constants reported in this study from the range given above are due to differences in the materials used and the temperatures of incubation.

As mentioned in 4.3.1, the improvement in R^2 and RMSE values of first order E over classical first order can be attributed to the additional term (Ne) in the former . The term easily accommodates the mineralizable N in the organic pool with negative sign (Table 4.5) which accounted for initial lag in the decomposition process. Comparison of the theoretical and experimental curves of cumulative net N released also indicated that first order E is better than simple first order model (Table 4.5 and Fig. 4.3).

TABLE 4.5: GOODNESS-OF-FIT STATISTICS AND PARAMETERS ESTIMATE FOR COMPARING THE KINETIC MODELS FITTED INTO CUMULATIVE NITROGEN ($NH_4^+ + NO_3^-$) RELEASED FROM SOIL INCUBATED WITH NEEM CAKE

Model	R^2	RMSE	No	Ne	k
First order	0.926	33.88	392		0.196
First order E	0.978	20.03	489	-131	0.324

4.3.4 Synchronization of Net Nitrogen Mineralized with Nitrogen Requirements for Maize

The N demands by crops must synchronize with the N supply from soil if maximum yield is to be achieved. This can be demonstrated by calculating the half life ($t_{1/2}$) for mineralization of soil incubated with neem cake. For first order E model, $t_{1/2}$ = 2.13 weeks while it is 3.6 weeks when the classical first order model is used.

Since first order E model has proved superior to the unmodified first order model in this study, $t_{1/2}$ of the former would be used. This $t_{1/2}$ has an implication on the timing of application of neem cake. Maize being a cereal crop with a high N demand has a critical period in which N fertilizer must be applied if a bountiful harvest is to be achieved. This coincides with the tasseling period (8 weeks after planting for a maize with a life span of 3 months). Addition of fertilizer after this period does not increase grain yield. Therefore, if neem cake is to be used as soil amendment it should be added to the soil at least $2\frac{1}{2}$ weeks before tasseling period ($5\frac{1}{2}$ weeks after planting for a maize with a life span of 3 months). Application of neem cake at this period would ensure the release of half of the potentially mineralizable N for crop utilization.

4.4 Green House Studies

4.4.1 Effect of Soil Amendments on Soil Available Phosphorus

The effect of neem cake with and without urea on the soil available P are shown in Tables 4.6 and 4.7. At all levels, neem cake does not mineralize enough P required by maize. All the maize grown in the first cropping session exhibited P deficiency symptoms with pronounced effect at lower level of neem cake treatment.

Investigations have shown that the activity of soil P depends on soil pH (Forth, 1978). Increase in soil acidity enhances the activity of micronutrients such as Fe, Al and Mn which in turn fix soluble phosphate as insoluble compounds making them unavailable to plants. In this study, soil acidity found to increase with increase in the quantity of cake applied (Table 4.8). Thus, most of the P that might have been mineralized are converted to insoluble form. Hence the decrease observed in soil available P with increasing quantity of neem cake in soil.

TABLE 4.6: EFFECT OF NEEM CAKE ON SOIL AVAILABLE PHOSPHORUS AFTER FIRST PLANTING

Cake Levels (kg/ha)	Soil Available Phosphorus (mg/kg)
0	1.46 c
80	2.94 a
120	2.05 bc
240	3.02 a
480	2.56 ab
960	2.35ab

S.E. = 0.23

Means with the same letter are not significantly different at 5% confidence level by DMRT. The Planting lasted for six weeks.

TABLE 4.7: INTERACTIVE EFFECT OF NEEM CAKE AND UREA ON SOIL AVAILABLE PHOSPHORUS AFTER FIRST PLANTING

Urea Levels (kg/ha)	Cake Levels (kg/ha)	Soil Available Phosphorus (mg/kg)
40	80	2.27 b
40	120	1.15 bc
40	240	4.51 a
40	480	2.27 b
40	960	1.61 b
80	80	2.05 b
80	120	0.92 c
80	240	1.83 b
80	480	1.80 b
80	960	0.93 c

S.E. = 0.40

Means with the same letter are not significantly different at 5% confidence level by DMRT. The planting lasted for six weeks.

TABLE 4.8: EFFECTS OF NEEM CAKE, UREA AND INTERACTIVE EFFECT OF NEEM CAKE AND UREA ON SOIL ACIDITY AFTER FIRST, SECOND AND THIRD PLANTINGS

Cake Level (kg/ha)	Urea Levels (kg/ha)	<---------- pH ---------->		
		First Planting	Second Panting	Third Planting
0	0	6.33 ± 0.2	5.92 ± 0.3	5.81 ± 0.2
80	0	5.38 ± 0.5	5.71 ± 0.1	5.61 ± 0.3
120	0	5.40 ± 0.4	5.93 ± 0.4	5.63 ± 0.1
240	0	5.29 ± 0.1	5.85 ± 0.2	5.64 ± 0.2
480	0	4.96 ± 0.3	5.29 ± 0.1	5.32 ± 0.3
960	0	5.24 ± 0.2	4.99 ± 0.1	5.19 ± 0.2
0	40	5.56 ± 0.1	5.53 ± 0.1	5.54 ± 0.1
0	80	5.40 ± 0.2	5.69 ± 0.2	5.47 ± 0.2
0	120	5.22 ± 0.2	5.50 ± 0.3	5.47 ± 0.1
80	40	5.32 ± 0.2	5.63 ± 0.2	5.66 ± 0.3
120	40	5.28 ± 0.1	5.36 ± 0.1	5.81 ± 0.2
240	40	5.19 ± 0.3	5.45 ± 0.2	5.69 ± 0.3
480	40	5.09 ± 0.2	5.09 ± 0.1	5.48 ± 0.2
960	40	5.20 ± 0.1	5.12 ± 0.2	5.32 ± 0.1
80	80	5.24 ± 0.4	5.42 ± 0.2	5.59 ± 0.2
120	80	4.94 ± 0.2	5.17 ± 0.1	5.36 ± 0.2
240	80	4.88 ± 0.3	5.45 ± 0.2	5.59 ± 0.3
480	80	4.89 ± 0.2	4.89 ± 0.3	5.43 ± 0.2
960	80	5.06 ± 0.1	5.10 ± 0.1	4.41 ± 0.1

Each planting lasted for six weeks.

4.4.2 Effect of Neem Cake on Maize Dry Matter Yield

The main effects of applicaiton of neem cake on shoot dry matter yield (SDMY) and root dry matter yield (RDMY) of maize are shown in Table 4.9. At each of the planting period, a general increase of SDMY and RDMY with increasing quantity of neem cake were observed. Dry matter yield (DMY) obtained when cake was applied at 240kgN/ha and above was better than when urea was applied at 120kgN/ha (standard experiment).

The response of maize dry matter yield to application of neem cake in the three plantings showed significant differences in all the treatments from control yield. Neem cake applied at 480 and 960kgN/ha significantly increased DMY at all the plantings. The observed increase in SDMY and RDMY in the second harvest over the first harvest was due to phosphate (KH_2PO_4) added to the soil. The addition was necessary to arrest deficiency of P noted in the plants during the first cropping. The yield obtained in the third cropping decreased possibly due to disappearance of more labile organic N and the predominance of the more recalcitrant organic N. This situation would lead to slow release of inorganic N, therefore, the lower yield recorded as compared to the first and second cropping sessions.

Table 4.9 also shows a general increase in cumulative SDMY and RDMY with increasing quantity of neem cake applied. The increase in yields obtained in this study is in agreement with findings of earlier researchers (Abdulrahman, 1989; Tarfa, 1994; Agbim and Adeoye, 1991).

TABLE 4.9: MAIN EFFECT OF NEEM CAKE ON DRY MATTER YIELD (g/pot) OF SHOOT AND ROOT OF MAIZE

Cake Levels (kg/ha)	First Planting		Second Planting		Third Planting		Cumulative	
	SDMY	RDMY	SDMY	RDMY	SDMY	RDMY	SDMY	RDMY
0	3.76 d	2.53 d	5.06 c	3.13 c	1.86 c	1.44 d	10.68 d	7.09 c
80	4.14 cd	3.09 cd	8.05 b	4.40 b	1.73 c	1.61 cd	13.91 c	9.09 b
120	4.67 c	3.53 bc	7.34 b	4.11 b	1.89 c	1.64 cd	13.90 c	9.27 b
240	6.00 b	3.47 bc	8.57 b	4.06 b	2.06 bc	1.75 c	16.62 b	9.92 b
480	7.61 a	4.20 b	12.86 a	5.45 a	2.41 b	2.00 b	22.89 a	11.65 a
960	6.64 b	5.40 a	12.97 a	4.58 b	3.49 a	2.83 a	23.10 a	12.81 a
S.E.	0.22	0.31	0.60	0.26	0.15	0.07	0.66	0.42

Means with the same letter are not significantly different at 5% confidence level by DMRT. Each planting lasted 6 weeks.

4.4.3 Effect of Urea on Maize Dry Matter Yield

The effect of urea on SDMY and RDMY of maize is given on Table 4.10. All the treatments indicated differences in DMY from control pot. When urea were applied at 0 and 40kgN/ha, there were no significant differences in SDMY and RDMY at first and second planting respectively. Urea fertilizer increased dry matter yield when compared with neem cake applied at corresponding rate possibly due to increase in nutrient availability. The observed increase in yields in second harvest over what was obtained at first harvest was due to KH_2PO_4 added. The recommended rate of fertilizer application is 120KgN/ha. Urea applied at 120KgN/ha is the standard experiment for this study.

TABLE 4.10: EFFECT OF UREA ON DRY MATTER YIELD (g/pot) OF SHOOT AND ROOT OF MAIZE

Urea Levels (kg/ha)	First Planting		Second Planting		Third Planting		Cumulative	
	SDMY	RDMY	SDMY	RDMY	SDMY	RDMY	SDMY	RDMY
0	3.76	2.53	5.06	3.13	1.86	1.41	10.68	7.09
40	5.06b	3.77b	9.13b	4.72a	2.31ab	1.82a	16.50b	10.30a
80	6.00a	4.40a	10.67a	4.32ab	2.39a	1.94a	19.06a	10.66a
120	5.26	3.36	8.40	4.76	1.80	1.80	15.47	9.92
S.E.	0.16	0.22	0.42	0.19	0.11	0.05	0.17	0.28

Means with the same letter are not significantly different at 5% confidence level by DMRT. Each planting lasted 6 weeks.

4.4.4 Interactive Effect of Neem Cake and Urea on Dry Matter Yield of Maize

The interactive effect of urea and neem cake on the dry matter yield of maize is shown on Table 4.11. At all rates, the interactive effect of amendments gave higher yield than treatment without urea and neem cake (Tables 4.9 and 4.10). Generally, DMY increased with increase in the quantity of neem cake applied when the quantity of urea applied was 80kgN/ha. This was not the case when the urea level was maintained at 40kgN/ha.

The interactive effect of cake and urea appears to increase soil acidity (Table 4.8) with negative consequence on nutrient availability. This might be responsible for differences obtained in SDMY when cake was applied at different levels compared to when corresponding quantity of cake was applied in the mixture of cake and urea. Significant differences were noted at all levels of cakes when urea was applied at 80kgN/ha. The increase in DMY at second planting over what was observed at first planting could be attributed to addition of KH_2PO_4 to the soil after first cropping. The decrease in SDMY and RDMY noted at third cropping scheme was possibly due to exhaution of organic substrate in the soil. DMY of neem cake applied at 240kgN/ha and above is higher than standard experiment (urea applied at 120kgN/ha) irrespective of the rate at which urea was applied in the interaction of neem cake and urea.

TABLE 4.11: INTERACTIVE EFFECT OF NEEM CAKE AND UREA ON DRY MATTER YIELD (g/pot) OF SHOOT AND ROOT OF MAIZE

Urea Levels (kg/ha)	Cake Levels (kg/ha)	First Planting		Second Planting		Third Planting		Cumulative	
		SDMY	RDMY	SDMY	RDMY	SDMY	RDMY	SDMY	RDMY
40	80	4.46e	3.33c	7.05d	4.39ab	1.59d	1.64cd	13.11d	9.36bc
40	120	4.17e	4.12bc	7.52d	5.60a	1.85d	1.63cd	13.55cd	11.35ab
40	240	5.69cd	3.62c	7.40d	3.61b	2.21c	1.74c	15.31c	9.00c
40	480	7.16b	3.54c	13.65a	5.72a	2.48c	2.15b	23.30a	11.41ab
40	960	5.05cd	5.70ab	13.81a	5.21a	3.99a	2.37ab	22.89ab	13.32a
80	80	4.04e	3.70c	10.70bc	5.26a	1.74d	1.54d	16.48c	10.50b
80	120	4.60de	3.92c	7.90cd	3.57b	2.25c	1.98bc	11.76c	9.46b
80	240	6.92b	3.67c	11.64ab	4.73a	2.08cd	1.58cd	20.64b	9.98b
80	480	9.54a	5.68ab	13.62a	4.77a	2.89bc	2.36ab	26.04a	12.82a
80	960	6.45bc	6.41a	13.17a	3.89b	3.36b	2.81a	22.99ab	13.12a
	S.E	0.38	0.54	1.03	0.45	0.26	0.12	1.86	0.73

Means with the same letter are not significantly different at 5% confidence level by DMRT. Each planting lasted 6 weeks.

4.4.5 Effect of Neem Cake on Nitrogen Uptake by Maize

The N uptakes of shoot (NS) and root (NR) by maize are influenced by addition of neem cake in the three croppings as shown on Table 4.12. In the second cropping, NS and NR were observed to be lower than first cropping despite in increase in SDMY and RDMY recorded. Addition of KH_2PO_4 might have aided uptake of other nutrients in addition to uptake of P leading to increase in DMY.

The observed increase in nutrient uptake with increase in the quantity of organic amendment is consistent with the findings of Cheng (1987), Akinyemi and Akinwale (1987), Abdulrahman (1989) and Tarfa (1994). N uptake of neem cake applied at 120kgN/ha and above were higher than standard experiment (Tables 4.12 and 4.13).

TABLE 4.12: EFFECT OF NEEM CAKE ON NITROGEN UPTAKE (mg/g) OF SHOOT AND ROOT OF MAIZE

Cake Levels (kg/ha)	First Planting		Second Planting		Third Planting		Cumulative	
	NS	NR	NS	NR	NS	NR	NS	NR
0	15.18f	11.69e	8.30d	5.91e	9.82b	7.95d	33.30f	25.58e
80	20.78e	13.90d	7.89d	6.32e	10.52ab	9.82bc	39.19e	30.03d
120	23.35d	16.87c	11.96c	8.01d	9.93b	9.23c	45.24d	34.11c
240	26.13c	18.76bc	12.15c	9.12c	9.93b	9.82bc	48.21d	37.69b
480	28.18b	21.09a	15.18b	11.81b	10.87ab	11.10a	54.23b	44.00a
960	36.13a	20.51ab	22.88a	14.13a	11.22a	10.28ab	70.23a	45.22a
S.E.	0.36	0.69	0.64	0.30	0.34	0.33	0.83	0.90

Means with the same letter are not significantly different at 5% confidence level by DMRT. Each planting lasted 6 weeks.

4.4.6 Effect of Urea on Nitrogen uptake by Maize

The NS and NR as influenced by addition of urea fertilizer are shown in Table 4.13. Significant differences were noted on the treated plants over control experiment. NS and NR increased with increase in the quantity of urea applied up to 80kgN/ha. Urea application at 40 and 80kgN/ha improved N uptake at first and second plantings when compared with neem cake that were applied at 120 and 240kgN/ha respectively (Table 4.12). The difference might be due to higher available N for plant uptake in the urea than in the neem cake where the N present is organically binded.

4.4.7 Interactive Effect of Neem Cake and Urea on Nitrogen Uptake by Maize

Higher N uptake was recorded in the shoot when neem cake and urea were interacted at different levels of treatment (Table 4.14) than when neem cake or urea alone were applied at corresponding rates (Tables 4.12 and 4.13). N uptakes were found to increase with increase in the quantity of neem cake applied at fixed level of urea. The insignificant differences recorded at third planting might be due to exhaution of mineralizable organic pool in the soil. Translocation of N uptake to the shoot is likely to be responsible for the results obtained at first planting.

The higher yields and N uptakes obtained as a result of interaction between neem cake and urea suggests that positive interaction exists between neem cake and urea. The synthetic fertilizer might have created enabling environment for the soil microbes thereby accelerating the rate of mineralization of organic substrates, thus inhibiting the net immobilization of nutrients. Generally, N uptakes for all levels of treatment were higher than standard experiment (Tables 4.14 and 4.13 respectively).

TABLE 4.13 EFFECT OF NEEM CAKE ON NITROGEN UPTAKE (mg/g) OF SHOOT AND ROOT OF MAIZE

Urea Levels (kg/ha)	First Planting		Second Planting		Third Planting		Cumulative	
	NS	NR	NS	NR	NS	NR	NS	NR
0	15.18	11.69	8.30	5.94	9.82	7.95	33.30	25.58
40	25.95b	17.68b	12.91b	8.92b	9.64b	9.58a	48.50a	36.18b
80	27.04a	19.42a	24.25a	10.59a	10.56a	9.53a	51.86a	39.54a
120	18.57	15.42	9.82	6.06	11.22	7.02	39.61	28.50
S.E.	0.26	0.49	0.45	0.21	0.24	0.24	0.58	0.64

Means with the same letter are not significantly different at 5% confidence level by DMRT. Each planting lasted 6 weeks.

TABLE 4.14: INTERACTIVE EFFECT OF NEEM CAKE AND UREA ON NITROGEN UPTAKE (mg/g) OF SHOOT AND ROOT OF MAIZE

Urea Levels (kg/ha)	Cake Levels (kg/ha)	First Planting		Second Planting		Third Planting		Cumulative	
		NS	NR	NS	NR	NS	NR	NS	NR
40	80	19.27e	11.37b	6.67d	6.11e	10.17a	10.17a	36.10e	30.67d
40	120	26.27d	14.17b	11.22c	8.59d	9.82ab	9.47ab	47.0cd	32.23d
40	240	28.77c	21.02a	13.32bc	9.12d	8.42b	9.12b	50.15bc	39.25c
40	480	29.07c	21.25a	15.07b	10.01c	9.82ab	9.82a	53.95b	41.08c
40	960	36.24b	23.33a	23.47a	13.50b	10.52a	11.22a	70.23a	48.05a
80	80	25.22d	16.12b	7.89d	6.67e	10.87a	9.82a	43.98d	32.60d
80	120	25.92c	22.42a	16.27b	9.29cd	10.17a	8.42b	52.35b	40.13e
80	240	28.30c	21.95a	12.97c	10.87c	11.22a	10.52a	52.48b	43.33bc
80	480	28.50c	21.72a	15.07b	14.88ab	10.17a	10.52a	53.73b	47.12a
80	960	38.17a	21.72a	23.47a	15.77a	10.52a	9.12b	72.15a	46.60ab
	S.E	0.62	1.20	1.11	0.52	0.58	0.58	1.43	1.57

Means with the same letter are not significantly different at 5% confidence level by DMRT. Each planting lasted 6 weeks.

CHAPTER FIVE

CONCLUSION

The soil used for the study have inherently low fertility status. The fitting of first order and modified first order rate equations in to laboratory incubation studies data quantified the potentially mineralizable N. From the calculated half lives, simple first order and modified first order rate equations indicated that neem cake should be added to maize at $4\frac{1}{2}$ and 6 weeks after planting (for maize that tassels at 8th week of planting). It is therefore suggested that if neem cake is to be used as soil amendement, it should be added to maize at least $5\frac{1}{2}$ weeks after planting (for a maize that tassels at 8th week of planting). This would ensure the release of half of the potentially mineralizable N for maize utilization during reproductive stage.

The use of neem cake, urea and interaction of these increased DMY over control pot. The DMY increased with increase in the rate of application of amendments. DMY of neem cake applied at 240kgN/ha and above were higher than standard experiment (urea applied at 120kgN/ha). Similarly, the DMY obtained when cake were applied at 240kgN/ha and above were higher than standard experiment irrespective of the rate at which urea were applied in the interaction of neem cake and urea. N uptake significantly increased with increase in the rate of application of soil amendments too. All the amendments used increased soil acidity when compared to control experiment.

With the rising cost of commercial fertilizers, neem cake which contain about 6.9% N could provide plant nutrients. However, there will be the need to supplement P through other sources because of the low content of P released into the soil from neem cake. Added to this, is the danger of making the soil acidic when large quantities of the organic materials are used. The increase in soil acidity could also lead to micronutrients deficiency.

This study is based on green house studies and may not necessarily give the same result on the field. Therefore, further studies on the effectiveness of using neem cake under field condition should be carried out.

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